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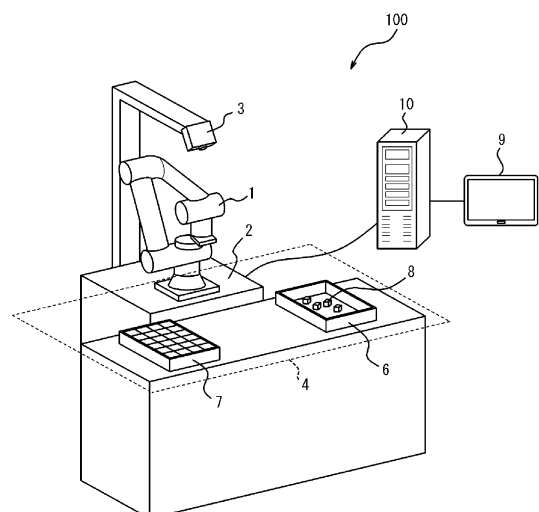(74) Representative: **TBK
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(54) **INFORMATION PROCESSING DEVICE, ROBOT CONTROLLER, ROBOT CONTROL SYSTEM, AND INFORMATION PROCESSING METHOD**

(57)   An information processing device includes a controller. The controller estimates the suitability of a candidate first control program to control a first robot from a plurality of control programs to control a robot which are recorded in a memory. The controller acquires first environmental information indicating a work environment of the first robot. The controller acquires second environmental information indicating an environment in which the first control program is to be executed. The controller estimates the suitability of a candidate first control program on the basis of a similarity between the first environmental information and the second environmental information.

FIG. 1

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Description

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims priority based on Japanese Patent Application No. 2021-158480 (filed September 28, 2021), the entire disclosure of which is hereby incorporated by reference.

TECHNICAL FIELD

[0002] The present disclosure relates to an information processing device, a robot controller, a robot control system, and an information processing method.

BACKGROUND OF INVENTION

[0003] A known device in the related art causes a robot to perform a group of tasks even if instructions from a user are lacking (see Patent Literature 1 for example).

CITATION LIST

PATENT LITERATURE

[0004] Patent Literature 1: Japanese Unexamined Patent Application Publication No. 2021-30407

SUMMARY

[0005] In an embodiment of the present disclosure, an information processing device includes a controller. The controller estimates the suitability of a candidate first control program to control a first robot from a plurality of control programs to control a robot which are recorded in a memory. The controller acquires first environmental information indicating a work environment of the first robot. The controller acquires second environmental information indicating an environment in which the first control program is to be executed. The controller estimates the suitability of a candidate first control program on the basis of a similarity between the first environmental information and the second environmental information.

[0006] In an embodiment of the present disclosure, a robot controller controls the robot by executing a control program outputted upon being determined to be in a suitable state in the information processing device.

[0007] In an embodiment of the present disclosure, a robot control system includes the information processing device, the robot controller, and the robot.

[0008] In an embodiment of the present disclosure, an information processing method is executed by an information processing device to estimate the suitability of a candidate first control program to control a first robot from a plurality of control programs to control a robot which are recorded in an information processing device. The information processing method includes acquiring, by the information processing device, first environmental infor-

mation indicating a work environment of the first robot. The information processing method includes acquiring, by the information processing device, second environmental information indicating an environment in which the first control program is to be executed. The information processing method includes estimating, by the information processing device, the suitability of a candidate first control program on the basis of a similarity between the first environmental information and the second environmental information.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009]

    FIG. 1 is a schematic diagram illustrating a configuration example of a robot control system according to an embodiment.
    FIG. 2 is a block diagram illustrating an example of the configuration of a robot control system according to an embodiment.
    FIG. 3 is a diagram illustrating an example of a work environment image.
    FIG. 4 is a table indicating an example of attribute information for objects located in a work environment.
    FIG. 5 is a table illustrating types of combinations of a selected control program and an actual work environment.
    FIG. 6 is a flowchart illustrating an example of a procedure to associate a control program with past record information.
    FIG. 7 is a flowchart illustrating an example of a procedure of an information processing method according to an embodiment.

DESCRIPTION OF EMBODIMENTS

(Overview of robot control system 100)

[0010] As illustrated in FIGs. 1 and 2, in one embodiment, a robot control system 100 includes a robot 1, a robot controller 2, an information acquisition device 3, a terminal device 9, and an information processing device 10. The robot control system 100 causes the robot 1 to perform tasks on objects placed on top of a workbench 5 located in a work environment 4. Specifically, for example, the robot 1 can move a workpiece 8 stored in a first tray 6 to a second tray 7.

[0011] A program to control the action of the robot 1 may be created as a user actually manipulates the robot 1, for example. A created program may be saved in the robot controller 2 or the information processing device 10. A program to control the action of the robot 1 is also referred to as a control program. Note that a control program may also be created using a robot simulator or the like. In this case, a control program may be created while not connected to a network (while offline), for example.

[0012] The robot 1 performs a task by acting according to a certain processing pattern. A processing pattern is represented, for example, as a combination of actions by which the robot 1 achieves a designated task. For example, a processing pattern may be represented as a combination of an action to grasp a workpiece 8, an action to convey the grasped workpiece 8, and an action to place the conveyed workpiece 8 in a certain position. A task is assumed to be a concept defining a goal to be achieved by performing a series of actions included in a processing pattern. As an example, a task may be a concept defining the goal of carrying a workpiece 8 from point A to point B. As another example, a task may be a concept defining the goal of placing a workpiece 8 at point C. As another example, a task may be a concept defining the goal of combining a workpiece 8 with another object. A processing pattern can be thought of as a combination of actions by which the robot 1 accomplishes a task. A control program can also be thought of as a group of commands causing the robot 1 to perform a combination of actions represented by a processing pattern so that the robot 1 can accomplish a task. In other words, a control program can be said to be software containing a programmed processing pattern for achieving a certain task. Note that a plurality of control programs may include control programs that each record different tasks to be performed on the same type of workpiece 8, or control programs that each record the same type of task to be performed on different types of workpieces 8. One type of task with respect to one type of workpiece 8 may also be programmed in a single control program.

[0013] When causing the robot 1 to perform a single task, a single control program corresponding to the task to be performed is prepared in advance. When causing the robot 1 to perform a plurality of tasks, a plurality of control programs corresponding to the tasks are prepared in advance. The user causes the robot 1 to perform a task by selecting a control program corresponding to the desired task that the robot 1 is to perform, and giving an instruction to the robot controller 2.

[0014] An increase in the number of control programs that have been prepared in advance may increase the difficulty for the user to suitably select a control program. For example, the user might select the wrong control program. In preparing the work environment 4 in which to cause the robot 1 to perform a task, the user might place the wrong types of objects, the wrong number of objects, or place objects in the wrong arrangement in the work environment 4.

[0015] As a comparative example, consider the case in which a workpiece in the robot controller estimates a workpiece present in the work environment on the basis of a captured image of the work environment, and estimates a task that a robot is to perform on the workpiece present in the work environment. However, according to the method of estimating a task as in the comparative example, when the possibility exists that a plurality of different tasks may be performed on the same workpiece,

or when the wrong workpiece is placed in the work environment, for example, the robot controller will have difficulty determining a suitable task.

[0016] In an embodiment according to the present disclosure, the information processing device 10 of the robot control system 100 acquires information about at least a portion of the work environment 4 of the robot on the basis of an image of at least a portion of the work environment 4 captured by the information acquisition device 3. The information processing device 10 of the robot control system 100 compares information about at least a portion of the work environment 4 with information associated with a control program serving as a candidate. The information processing device 10 of the robot control system 100 can determine whether a control program serving as a candidate is suitable as a control program to cause the robot to perform a task. The information processing device 10 of the robot control system 100 can determine whether a control program serving as a candidate is suitable with respect to the work environment 4. The information processing device 10 of the robot control system 100 can determine whether the work environment 4 is suitable as an environment in which to carry out a control program serving as a candidate.

[0017] In other words, the information processing device 10 of the robot control system 100 estimates the suitability of a candidate control program to control the robot 1 under control from a plurality of control programs to control the robot 1 which are recorded in a memory 12 of the information processing device 10. The robot 1 under control is also referred to as the first robot simply for the sake of distinction. A control program to control the first robot is also referred to as the first control program simply for the sake of distinction.

[0018] Note that when a user-selected control program is not suitable with respect to the work environment 4, the information processing device 10 of the robot control system 100 may notify the user, and may also extract and present a suitable control program. This arrangement may lower the possibility of the user selecting the wrong control program.

(Example of configuration of robot control system 100)

[0019] As illustrated in FIGs. 1 and 2, in one embodiment, a robot control system 100 includes a robot 1, a robot controller 2, an information acquisition device 3, a terminal device 9, and an information processing device 10. At least one configuration portion of the robot control system 100 may be communicatively connected through a network 80, or may be communicatively connected without going through the network 80. At least one configuration portion of the robot control system 100 may be communicatively connected in a wired or wireless way. At least one configuration portion of the robot control system 100 may be communicatively connected through a dedicated channel. At least one configuration portion of the robot control system 100 is not limited to these ex-

amples, and may be communicatively interconnected in any of various other forms. The following describes the configurations of the robot control system 100 specifically.

information processing device 10>

[0020] The information processing device 10 includes a controller 11 and a memory 12. The information processing device 10 is communicatively connected to other configuration portions through the network 80, or directly without going through the network 80.

[0021] The controller 11 may include at least one processor to achieve various functions of the information processing device 10. The processor may execute a program to achieve the various functions of the information processing device 10. The processor may be achieved as a single integrated circuit. An integrated circuit is also referred to as an IC. The processor may be achieved as a plurality of communicatively connected integrated circuits and discrete circuits. The processor may include a central processing unit (CPU). The processor may include a digital signal processor (DSP) or a graphics processing unit (GPU). The processor may be achieved on the basis of any of various other known technologies.

[0022] The information processing device 10 further includes a memory 12. The memory 12 may include an electromagnetic storage medium such as a magnetic disk, or a memory such as semiconductor memory or magnetic memory. The memory 12 may be configured as a hard disk drive (HDD) or as a solid-state drive (SSD). The memory 12 stores various information, programs to be executed by the controller 11, and the like. The memory 12 may function as a working memory of the controller 11. At least a portion of the memory 12 may be included in the controller 11. At least a portion of the memory 12 may be configured as a storage device separate from the information processing device 10.

[0023] The information processing device 10 may include a communication device configured to communicate in a wired or wireless way. The communication device may be configured to communicate according to a communication scheme based on any of various communication standards.

[0024] The information processing device 10 may include one or more servers. The information processing device 10 may cause a plurality of servers to execute parallel processing. The information processing device 10 does not necessarily include a physical housing, and may also be configured on the basis of virtualization technology such as a virtual machine or a container orchestration system. The information processing device 10 may also be configured using a cloud service. When configured using a cloud service, the information processing device 10 may be configured by combining managed services. In other words, the functions of the information processing device 10 may be achieved as a cloud service.

[0025] The information processing device 10 may include at least one server cluster and at least one database cluster. The server cluster functions as the controller 11. The database cluster functions as the memory 12. One server cluster may be present. Two or more server clusters may also be present. In the case of one server cluster, the functions achieved by the one server cluster encompass the functions achieved by each server cluster. The server clusters are communicatively connected to each other in a wired or wireless way. One database cluster may be present. Two or more database clusters may also be present. The number of database clusters may be increased or decreased, as appropriate, on the basis of the volume of data to be managed by the information processing device 10 and the availability requirements of the information processing device 10. The database clusters are communicatively connected to the server clusters in a wired or wireless way. The information processing device 10 may also be connected to an external database. An information processing system including the information processing device 10 and the external database may also be configured.

[0026] The information processing device 10 is illustrated as a single configuration in FIGs. 1 and 2, but a plurality of configurations may be managed as a single system if necessary. In other words, the information processing device 10 is configured as a scalable platform. By using a plurality of configurations as the information processing device 10, even if one configuration becomes inoperable due to a natural disaster or other unforeseen event, the system will continue to operate using the other configuration(s). In this case, the plurality of configurations are interconnected by a wired and/or wireless channel and are capable of communicating with each other. The plurality of configurations may also be built across cloud and on-premises environments.

[0027] The information processing device 10 is communicatively connected to at least one configuration of the robot control system 100 by a wired and/or wireless channel. The information processing device 10 and the at least one configuration of the robot control system 100 are mutually equipped with interfaces using a standard protocol, allowing for bidirectional communication.

<Terminal device 9>

[0028] The terminal device 9 is communicatively connected to at least one configuration of the robot controller 2 or the information processing device 10 of the robot control system 100. Note that the terminal device 9 may also be communicatively connected to another configuration of the robot control system 100. The terminal device 9 and the at least one configuration of the robot control system 100 may be communicatively connected through the network 80, or directly without going through the network 80.

[0029] The terminal device 9 may include at least one processor. The processor of the terminal device 9 may

be the same and/or similar to the processor in the controller 11 of the information processing device 10. The terminal device 9 may include a storage device. The storage device of the terminal device 9 may be the same and/or similar to the memory 12 of the information processing device 10. The terminal device 9 may include a communication device. The communication device of the terminal device 9 may be the same and/or similar to the communication device of the information processing device 10.

[0030] The terminal device 9 may include an input device. The input device may include a touch panel or touch sensor, or a pointing device such as a mouse, for example. The input device may also include physical keys. The input device may also include a voice input device such as a microphone. The input device is not limited to these examples and may include any of various other devices.

[0031] The terminal device 9 may include an output device. The output device may include a display device. The display device may include a liquid crystal display (LCD), an organic electroluminescence (EL) display or inorganic EL display, a plasma display panel (PDP), or the like. The display device is not limited to these displays and may include any of various other types of displays. The display device may include a light-emitting device such as a light-emitting diode (LED). The display device may include any of various other devices. The output device may also include a speaker or other sound output device that outputs auditory information such as speech. The output device is not limited to these examples and may include any of various other devices.

[0032] The terminal device 9 included in the robot control system 100 is not limited to one, and may also number two or more. When the robot control system 100 includes a plurality of terminal devices 9, each terminal device 9 may accept input from a user. The terminal device 9 may be configured as a tablet terminal. The terminal device 9 may be configured as a mobile phone terminal such as a feature phone or a smartphone. The terminal device 9 may be configured as a personal computer (PC) terminal such as a desktop PC or a laptop PC. The terminal device 9 is not limited to these examples and may be configured as any of various devices capable of providing a graphical user interface (GUI) and a communication function.

[0033] The terminal device 9 may be used by a user to perform a task of storing a control program in the information processing device 10 in advance. The terminal device 9 may also be used to monitor the state of the robot 1. The terminal device 9 is not limited to these examples and can provide any of various other functions. The terminal device 9 may also be provided as part of the robot controller 2. When the terminal device 9 is provided as part of the robot controller 2, the robot controller 2 itself may include an input device or an output device. The robot controller 2 may also be included in the terminal device 9.

<Robot controller 2>

[0034] The robot controller 2 downloads a control program from the information processing device 10. The robot controller 2 executes a downloaded control program, thereby outputting information for controlling the action of the robot 1 to the robot 1 and causing the robot 1 to perform a task specified by the control program. The robot controller 2 may also execute a control program that the robot controller 2 itself retains. As exemplified in FIG. 1, the robot controller 2 may cause the robot 1 to perform a task of moving a workpiece 8 from the first tray 6 to the second tray 7. The robot controller 2 may cause the robot 1 to perform any of various tasks not limited to the above. The robot controller 2 may or may not be connected to a cloud computing environment. When the robot controller 2 is not connected to a cloud computing environment, the action of the robot controller 2 is completed in the on-premises environment. When the action of the robot controller 2 is completed in the on-premises environment, the action of the information processing device 10 is executed by the robot controller 2.

[0035] The robot controller 2 may include a communication device that downloads a control program from the information processing device 10. The communication device of the robot controller 2 may be the same and/or similar to the communication device of the information processing device 10. The robot controller 2 may include a processor that generates information for controlling the action of the robot 1 by executing a control program. The processor of the robot controller 2 may be the same and/or similar to the processor in the controller 11 of the information processing device 10.

[0036] In the configuration exemplified in FIG. 1, one robot controller 2 is connected to one robot 1. One robot controller 2 may also be connected to two or more robots 1. One robot controller 2 may control only one robot 1, or may control two or more robots 1. The robot controllers 2 and robots 1 are not limited to two, and may also be number one, or number three or more. The robot controller 2 may also be unified with the information processing device 10 such that the function of the robot controller 2 is achieved as one function of the information processing device 10.

<Robot 1>

[0037] The robot 1 may be configured as a robotic arm including an arm. The arm may be configured as a 6-axis or 7-axis vertical articulated robot, for example. The arm may also be configured as a 3-axis or 4-axis horizontal articulated robot, for example. The arm may also be configured as a 2-axis or 3-axis Cartesian robot. The arm may also be configured as a parallel link robot or the like. The number of axes forming the arm is not limited to the examples given.

[0038] The robot 1 may include an end effector attached to the arm. The end effector may include, for ex-

ample, a grasping hand configured to grasp a work object. The grasping hand may have a plurality of fingers. The grasping hand may have two or more fingers. Each finger on the grasping hand may have one or more joints. The end effector may also include a suction hand configured to suction a work object. The end effector may also include a scooping hand configured to scoop up a work object. The end effector may also include a drill or other tool and may be configured to perform any of various machining actions, such as drilling a hole in a work object. The end effector is not limited to these examples and may be configured to perform any of various other actions.

[0039] The robot 1 can control the position of the end effector by actuating the arm. The end effector may have an axis that serves as a reference in the direction of action with respect to a work object. When the end effector has an axis, the robot 1 can control the direction of the end effector axis by actuating the arm. The robot 1 controls the start and end of an action to act on a work object. The robot 1 can move or machine a work object by controlling the action of the end effector while controlling the position of the end effector or the direction of the end effector axis.

[0040] The robot 1 may also be configured as an automated guided vehicle (AGV). The robot 1 may also be configured as a drone. The robot 1 is not limited to a robotic arm or AGV and may also be configured in any of various other forms, such as a vehicle, an electronic device, or a control machine.

[0041] The robot 1 may further include a sensor to detect the state of at least one configuration portion of the robot 1. The sensor may detect information about the real position or orientation of at least one configuration portion of the robot 1, or information about the velocity or acceleration of at least one configuration portion of the robot 1. The sensor may also detect a force acting on at least one configuration portion of the robot 1. The sensor may also detect a current flowing in, or the torque of, a motor used to drive at least one configuration portion of the robot 1. The sensor can detect information obtained as a result of an actual action by the robot 1. By acquiring a detection result from the sensor, the robot controller 2 can ascertain the result of an actual action by the robot 1.

[0042] Unlike a device that performs a certain task on a product and machines different types of products by being configured with conditions according to the type of product, the robot 1 is capable of generating a control program suited to a task, and can act to perform any of various tasks by generating control programs.

information acquisition device 3>

[0043] The information acquisition device 3 acquires information about at least a portion of the work environment 4 of the robot 1. The information acquisition device 3 may include a camera to capture an image of at least a portion of the work environment 4. The information ac-

quisition device 3 may include a sensor to measure the position, shape, or size of an object present in at least a portion of the work environment 4. The information acquisition device 3 may include a 3D sensor, a distance sensor, or the like. The information acquisition device 3 may include a sensor to measure the temperature, humidity, or the like of at least a portion of the work environment 4. When at least a portion of the work environment 4 is a cleanroom, the information acquisition device 3 may include a sensor to measure particle density inside the cleanroom. Information about at least a portion of the work environment 4 may also include cleanroom classification information. The information acquisition device 3 may include a sensor to measure noise in at least a portion of the work environment 4. The information acquisition device 3 may include a sensor such as a current sensor to measure a current or the like which indicates the running of peripheral equipment. The information acquisition device 3 may be fixed at a position allowing for the acquisition of information about at least a portion of the work environment 4 of the robot 1. The information acquisition device 3 may be attached to a robotic arm or an end effector. The information acquisition device 3 is not limited to one, and may also number two or more. A plurality of information acquisition devices 3 may be communicatively connected to each other. At least one among the plurality of information acquisition devices 3 may be communicatively connected to the robot controller 2 or the information processing device 10. The information acquisition device 3 may include a plurality of information acquisition units physically apart from each another. The plurality of information acquisition units may be communicatively connected to each other.

[0044] The information that the information acquisition device 3 acquires as at least a portion of the work environment 4 may also include information within a working range of the robot 1. The working range of the robot 1 may be a range containing the workbench 5 and any objects placed on the workbench 5, as exemplified in FIG. 1. The information that the information acquisition device 3 acquires as above at least a portion of the work environment 4 may also include information different from the work object itself or the robot 1 itself. The information that the information acquisition device 3 acquires as information on at least a portion of the work environment 4 is not limited to the above information and may also include information outside the working range of the robot 1. Specifically, the information that the information acquisition device 3 acquires as information on at least a portion of the work environment 4 may include information about a range containing peripheral equipment. The peripheral equipment may include a parts feeder to place the workpiece 8 or a tray changer to place the first tray 6, the second tray 7, or the like. The peripheral equipment may include a workpiece reversing device to reverse the workpiece 8 front-to-back/back-to-front. The peripheral equipment may include a tool changer to exchange the end effector of the robot 1. The peripheral

equipment may include a production device such as a grinder to machine the workpiece 8. The peripheral equipment is not limited to the above and may include any of various equipment. The information that the information acquisition device 3 acquires as information on at least a portion of the work environment 4 may also include information about a range not containing the workpiece 8. The information that the information acquisition device 3 acquires as information on at least a portion of the work environment 4 may include attribute information about the end effector of the robot 1 or attribute information about the arm. Attribute information about the end effector may include information specifying whether the end effector is a hand, a suction cup, or the like. Attribute information about the arm may include information specifying the number of joints or the movable range of the arm, or the length of the arm.

[0045] The range in which the information acquisition device 3 acquires information may be an action range of the robot 1. The range in which the information acquisition device 3 acquires information is not limited to the action range of the robot 1, and may also include a range outside or peripheral to the action range of the robot 1. The information acquisition device 3 may acquire information about a range outside or peripheral to the action range of the robot 1 as information about at least a portion of the work environment 4. The range peripheral to the action range may be a range within a certain distance from the action range. The certain distance may be set as the distance between two points inside the same factory building, the same room, or the same production line, for example. The peripheral equipment may include a conveyor belt that conveys the workpiece 8 or the like into the action range of the robot 1. The robot control system 100 may select a control program on the basis of the state of the workpiece 8 on the conveyor belt located outside the action range of the robot 1.

(Example of action of robot control system 100)

[0046] The robot control system 100 may store in the information processing device 10 a control program (processing pattern) mapped to a program number, a program name, or a task name. The robot control system 100 maps, to a program name or the like, information about at least a portion of the work environment 4 where a control program is to be executed. In other words, a control program is mapped to information about at least a portion of the work environment 4 where the control program is to be executed. User-prepared information about at least a portion of the work environment 4 is also referred to as prepared environmental information or first environmental information. Information about at least a portion of the work environment 4 associated with a control program is information about at least a portion of the work environment 4 when the control program was recorded in the past, and is also referred to as past record information or second environmental information. Past record information or second environmental information corresponds to information about at least a portion of the work environment 4 when the robot 1 performed a task in response to the robot controller 2 executing a control program. Past record information or second environmental information may also include user-registered information about at least a portion of the work environment 4. In the robot control system 100, the terminal device 9 may be configured to accept user input to register information about at least a portion of the work environment 4. In other words, the robot control system 100 may associate information simultaneously registered by a user with the number of the like of a robot control program (processing pattern). A user who can register past record information or second environmental information about the first robot may be, for example, a user who has caused the first robot to perform a task in the past, or a user of another robot. A user who can register past record information or second environmental information about the first robot may be someone such as an administrator or worker at a factory or the like.

[0047] Past record information may simply include information that can be compared to prepared environmental information. That is, past record information may simply include information corresponding to prepared environmental information. For example, if the prepared environmental information contains an image, the past record information may also contain an image. If the prepared environmental information contains sensor output or other numerical data, the past record information may also contain numerical data. Stated differently, prepared environmental information may also include information that can be compared to past record information.

[0048] Past record information may include an image of at least a portion of the work environment 4 captured when the control program is executed, for example. Past record information may include attribute information about an object present in at least a portion of the work environment 4. Attribute information may be obtained by analyzing an image of at least a portion of the work environment 4. Attribute information about an object may include information about the appearance of the object, such as the outline or other shape of the object, the color or texture of the object, or the size of the object. Attribute information about an object may include two-dimensional information captured in an image of at least a portion of the work environment 4, and may include three-dimensional information based on depth information about at least a portion of the work environment 4. Attribute information is not limited to information pertaining to the appearance of an object and may also include information about the material, density, or the like of the object. Past record information may include coordinates or other position information about an object present in at least a portion of the work environment 4. Position information may represent a relative position from a reference position set in the work environment 4. Position information may also represent an absolute position set in the infor-

mation acquisition device 3. Position information may also represent a positional relationship of a plurality of objects in the vicinity of the robot 1. Position information may also represent a positional relationship of a plurality of objects present in at least a portion of the work environment 4. Position information may also represent a positional relationship between a workpiece 8 and an object in the vicinity of the workpiece 8. Past record information may include image capture conditions, such as the type of camera used to capture an image of at least a portion of the work environment 4, or the camera position, orientation, or the like.

[0049] As described above, the robot control system 100 stores a control program mapped to a program number or a program name in the information processing device 10, in association with past record information about the control program. Specifically, the robot control system 100 may store the following information in the information processing device 10.

(1) Program number
(2) Control program (processing pattern)
(3) Captured image of at least a portion of the work environment 4
(4) Attribute information and position information about an object recognized from the captured image of at least a portion of the work environment 4

[0050] FIG. 3 illustrates an example of a captured image of at least a portion of the work environment 4. The workbench 5 is located in the work environment 4. The first tray 6 and the second tray 7 are located on top of the workbench 5. Workpieces 8 are stored in the first tray 6.

[0051] FIG. 4 illustrates an example of attribute information and position information about objects recognized from a captured image of at least a portion of the work environment 4. A total of 11 objects are recognized from the image. Four types of objects are present. To identify objects by type, an object ID numbered from 1 to 4 is assigned to each type. The workbench 5 is mapped to the number 1. The second tray 7 is mapped to the number 2. The first tray 6 is mapped to the number 3. The workpiece 8 is mapped to the number 4. One workbench 5, one first tray 6, and one second tray 7 are present. Eight workpieces 8 are present.

[0052] Color information about each object is represented as average color information obtained by averaging color information about each portion of an object. Color information is represented as numerical values corresponding to gradations of red, green, and blue (RGB) components of an image. The average color information about the workbench 5 (object ID = 1) is represented by (R1, G1, B1). The average color information about the second tray 7 (object ID = 2) is represented by (R2, G2, B2). The average color information about the first tray 6 (object ID = 3) is represented by (R3, G3, B3). The average color information about the workpiece 8 (object ID

= 4) is represented by (R4, G4, B4).

[0053] The outline and texture of each object is represented by an image of the object.

[0054] In this embodiment, the size of each object is assumed to be represented by the width (W) × depth (D) × height (H) of each object. The size of the workbench 5 (object ID = 1) is represented by W1×D1×H1. The size of the second tray 7 (object ID = 2) is represented by W2×D2×H2. The size of the first tray 6 (object ID = 3) is represented by W3×D3×H3. The size of the workpiece 8 (object ID = 4) is represented by W4×D4×H4.

[0055] The coordinates of each object may be represented by relative coordinates with respect to the coordinates of a reference position set in the work environment 4, or by absolute coordinates (for example, a pixel position in a captured image) set in the information acquisition device 3. In this embodiment, the coordinates are assumed to be represented by XYZ coordinates. The coordinates of the workbench 5 (object ID = 1) are represented by (X1, Y1, Z1). The coordinates of the second tray 7 (object ID = 2) are represented by (X2, Y2, Z2). The coordinates of the first tray 6 (object ID = 3) are represented by (X3, Y3, Z3). The coordinates of the workpiece 8 (object ID = 4) are represented by (X4, Y4, Z4).

<Association with past record information at time of execution of control program>

[0056] The robot control system 100 stores a control program in the information processing device 10 in advance. When a control program is not associated with past record information at the time of execution of the control program, the robot control system 100 may acquire information about at least a portion of the work environment 4 at the time of execution of the control program. The robot control system 100 may associate the acquired information about at least a portion of the work environment 4 with the control program as past record information. For example, when a control program is executed for the first time, the robot control system 100 may acquire information about at least a portion of the work environment 4 thereof as past record information, and associate the past record information with the control program. The robot control system 100 can also be said to associate past record information with a task corresponding to a control program. Past record information may also include user-registered information about at least a portion of the work environment 4. In the robot control system 100, the terminal device 9 may be configured to accept user input to register information about at least a portion of the work environment 4. In other words, the robot control system 100 may associate information simulatively registered by a user with the number of the like of a robot control program (processing pattern). A user who can register past record information about the first robot may be, for example, a user who has caused the first robot to perform a task in the past, or a user of another robot. A user who can register past record information

about the first robot may be someone such as an administrator or worker at a factory or the like.

[0057] A control program may be stored in the information processing device 10 in association with past record information according to the following procedure specifically.

[0058] In the robot control system 100, workpieces 8 and the like necessary for the robot 1 to perform a task are prepared as illustrated in FIG. 3. As an example, a user places the first tray 6 and the second tray 7 in the work environment 4. The user stores the workpieces 8 in the first tray 6. In other words, the user may place the workpieces 8 along with the first tray 6 and the second tray 7. As another example, peripheral equipment may place the workpieces 8 along with the first tray 6 and the second tray 7.

[0059] After preparing the workpieces 8 and the like in the work environment 4, the user uses the terminal device 9 to select a control program to be executed by the robot controller 2. The terminal device 9 outputs the selected control program to the robot controller 2. The robot controller 2 executes the acquired control program to thereby control the robot 1 and cause the robot 1 to perform a task.

[0060] When the robot 1 performs a task, the robot 1 or the robot controller 2 acquires information about at least a portion of the work environment 4 through the information acquisition device 3. For example, the information acquisition device 3 may capture an image of at least a portion of the work environment 4 and acquire the captured image of at least a portion of the work environment 4 as information about at least a portion of the work environment 4. When the information acquisition device 3 is attached to an arm or end effector of the robot 1, the robot 1 may move the information acquisition device 3 to a predetermined image capture position and cause the information acquisition device 3 to capture an image of at least a portion of the work environment 4. The information acquisition device 3 may acquire not only a captured image of at least a portion of the work environment 4 but also various information, such as depth information about at least a portion of the work environment 4, as information about at least a portion of the work environment 4.

[0061] The information acquisition device 3 outputs acquired information about at least a portion of the work environment 4 to the information processing device 10. The controller 11 of the information processing device 10 analyzes the information about at least a portion of the work environment 4 to recognize an object such as a workpiece 8 present in at least a portion of the work environment 4. For example, the controller 11 may recognize each of the workpieces 8, the first tray 6, and the second tray 7 through image analysis of a captured image of at least a portion of the work environment 4. For example, the controller 11 may recognize each of the workpieces 8, the first tray 6, and the second tray 7 by analyzing depth information about at least a portion of the work environment 4.

[0062] The controller 11 acquires attribute information and position information about each object recognized from the information about at least a portion of the work environment 4. The controller 11 associates attribute information and position information about each object with a control program stored in the memory 12 as past record information. As described above, a control program is stored in the information processing device 10 in association with past record information.

<Execution of control program associated with past record information>

[0063] The robot control system 100 associates a control program with past record information. This makes possible the following procedure for easily determining the suitability of a control program to be used to cause the robot 1 to perform a task in a prepared work environment 4. The robot control system 100 can also be said to estimate the suitability of a control program selected as a candidate when the user has selected a candidate control program to be used to cause the robot 1 to perform a task.

[0064] In the robot control system 100, workpieces 8 and the like necessary for the robot 1 to perform a task are prepared as illustrated in FIG. 3. As an example, a user places the first tray 6 and the second tray 7 in the work environment 4. The user stores the workpieces 8 in the first tray 6. In other words, the user may place the workpieces 8 along with the first tray 6 and the second tray 7. As another example, peripheral equipment may place the workpieces 8 along with the first tray 6 and the second tray 7.

[0065] The user activates the robot controller 2 or the robot 1 through the terminal device 9. After preparing the workpieces 8 and the like in the work environment 4, the user uses the terminal device 9 to select a control program to be executed by the robot controller 2. On the other hand, the robot control system 100 acquires information about at least a portion of the work environment 4 through the information acquisition device 3. When the information acquisition device 3 is attached to an arm or end effector of the robot 1, the robot controller 2 controls the action of the robot 1 to move the information acquisition device 3 to a certain position or point the information acquisition device 3 in a certain direction to acquire information about at least a portion of the work environment 4.

[0066] The information acquisition device 3 outputs acquired information about at least a portion of the work environment 4 to the information processing device 10. The controller 11 of the information processing device 10 analyzes the information about at least a portion of the work environment 4 to recognize an object such as a workpiece 8 present in at least a portion of the work environment 4. For example, the controller 11 may recognize each of the workpieces 8, the first tray 6, and the second tray 7 through image analysis of a captured image

of at least a portion of the work environment 4. For example, the controller 11 may recognize each of the workpieces 8, the first tray 6, and the second tray 7 by analyzing depth information about at least a portion of the work environment 4.

[0067] The controller 11 acquires attribute information and position information about each object recognized from the information about at least a portion of the work environment 4. The controller 11 compares the attribute information and position information about each object to past record information associated with a selected control program. If the past record information associated with the selected program conforms to the information about at least a portion of the work environment 4, the controller 11 outputs the selected control program to the robot controller 2. The robot controller 2 executes the selected control program and causes the robot 1 to perform a task.

«Extraction of control program based on similarity»

[0068] To determine whether the past record information associated with the selected program conforms to the information about at least a portion of the work environment 4, the controller 11 may compute a similarity between at least a portion of the work environment 4 and the past record information. The similarity is assumed to be computed such that the similarity is 100% when the two pieces of information are completely alike and 0% when the two pieces of information are completely unalike. When the similarity is a certain value or greater, the controller 11 may cause the robot controller 2 to execute the selected control program.

[0069] The controller 11 may compute the similarity as the similarity of attribute information such as the shape or color of objects present in at least a portion of the work environment 4. Specifically, the controller 11 compares attribute information about each object recognized from information about at least a portion of the work environment 4 to attribute information included in past record information associated with control programs stored in the information processing device 10. The controller 11 may compute the similarity as a numerical value by using template matching or a trained model generated by machine learning or deep learning. The controller 11 computes the similarity for each type of recognized object. The controller 11 computes the similarity for all types of recognized objects. Objects recognized in at least a portion of the work environment 4 exemplified in FIG. 3 are divided into four types. The controller 11 computes the similarity for each of the four types. The controller 11 calculates the mean and standard deviation of the four similarities computed for the types. When the mean is equal to or greater than a preset mean determination threshold value and the standard deviation is less than or equal to a preset standard deviation determination threshold value, the controller 11 determines that the past record information conforms to the information about at least a portion of the work environment 4. Note that in the case of using a trained model, the trained model can be generated by machine learning using a training dataset containing data pertaining to a plurality of past record information.

[0070] The controller 11 may compute the similarity as the similarity of the positions of objects present in at least a portion of the work environment 4. Specifically, the controller 11 computes the distance between objects on the basis of position information about each object recognized from information about at least a portion of the work environment 4. The position information about each object is assumed to include center-of-gravity coordinates for each object. The position information about each object may also include edge coordinates for each object (for example, minimum and maximum values of the X, Y, and Z coordinates of the range in which each object is present). The controller 11 computes the distance between objects on the basis of the center-of-gravity coordinates for each object. In the work environment 4 exemplified in FIG. 3, the controller 11 computes the distance between each of the workbench 5 (object ID = 1), the second tray 7 (object ID = 2), the first tray 6 (object ID = 3), and the workpieces 8 (object ID = 4). In the example in FIG. 3, eight objects are classified into the same type as the workpieces 8 (object ID = 4). The controller 11 calculates center-of-gravity coordinates for a plurality of objects classified into the same type by considering the plurality of objects as one object, and computes the distance to other objects. When four types of objects are present in the work environment 4, there are six combinations for which to compute the distance between objects. Accordingly, six distances between objects are computed.

[0071] The controller 11 computes the distance between objects included in past record information on the basis of position information included in past record information associated with control programs stored in the information processing device 10. The controller 11 may compute the distance between objects for past record information that includes four types of objects. When past record information includes objects corresponding to objects present in at least a portion of the work environment 4, the controller 11 may also compute the distance between objects. In other words, when past record information does not include objects corresponding to objects present in at least a portion of the work environment 4, the controller 11 may determine that the past record information does not conform to the information about at least a portion of the work environment 4, without computing the distance between objects in the past record information.

[0072] The controller 11 compares the distance between objects recognized from information about at least a portion of the work environment 4 to the distance between objects in past record information associated with a control program. The controller 11 selects two objects from the objects recognized from the information about

at least a portion of the work environment 4. From among the objects included in past record information, the controller 11 selects two objects that correspond to two objects selected from objects recognized from information about at least a portion of the work environment 4. The controller 11 computes the absolute value of the difference between the distance between two objects selected from objects recognized from information about at least a portion of the work environment 4 and two objects selected from objects included in past record usage. For each of the distances calculated for the six combinations in the example in FIG. 3, the controller 11 computes the absolute value of the distance between two objects included in information about at least a portion of the work environment 4 and the distance between two objects included in past record information. The controller 11 computes the mean and the standard deviation of the absolute values of the differences between the distances computed for all combinations as the similarity of position. When the mean is equal to or greater than a preset mean determination threshold value and the standard deviation is less than or equal to a preset standard deviation determination threshold value, the controller 11 determines that the past record information conforms to the information about at least a portion of the work environment 4.

[0073]   FIG. 5 illustrates an example of types of cases where past record information does not conform to information about at least a portion of the work environment 4. In the cell in the left column in the first row of FIG. 5, the type indicated as "correct combination" indicates the case where past record information associated with data (stored data) of a control program stored in the memory 12 of the information processing device 10 conforms to at least a portion of the work environment 4. Specifically, as illustrated in the cell in the right column in the first row, a control program with the program number No. 28 is associated with a configuration in which the first tray 6, the second tray 7, and the workpieces 8 are placed in the work environment 4.

[0074]   In the cell in the left column in the second row of FIG. 5, the type indicated as "wrong workpieces" indicates the case where the wrong workpieces 8 have been placed in the work environment 4 as compared to past record information associated with the data (selected data) of a user-selected control program. Specifically, the workpieces 8 should be stored in the first tray 6, but as illustrated in the cell in the right column in the second row, wrong workpieces 8F are stored in the first tray 6.

[0075]   In the cell in the left column in the third row of FIG. 5, the type indicated as "tray not set" indicates the case where the second tray 7 is missing from the work environment 4 as compared to past record information associated with the selected data. Specifically, the second tray 7 should be set, but as indicated as a missing tray 7F represented by the chain double-dashed line in the cell in the right column in the third row, the second tray 7 has not been set.

[0076]   In the cell in the left column in the fourth row of FIG. 5, the type indicated as "wrong program selected" indicates the case where the work environment 4 is as intended by the user, but the selected data is wrong. Specifically, the control program No. 28 should be selected as the selected data, but as illustrated in the middle column in the fourth row, the wrong control program No. 14 is selected.

[0077]   The types of cases where past record information does not conform to information about at least a portion of the work environment 4 are not limited to the above types. For example, the types may include a type in which an extra object is placed in at least a portion of the work environment 4. The types may also include a type in which the workpieces 8 are not placed.

[0078]   When the situation corresponds to one of the types exemplified in in the second to fourth rows of the table in FIG. 5 or any of various other types, the controller 11 determines that the past record information does not conform to the information about at least a portion of the work environment 4. The controller 11 may compute the similarity and use the similarity as a basis for determining that the past record information does not conform to the information about at least a portion of the work environment 4. The controller 11 may determine that the past record information does not conform to the information about at least a portion of the work environment 4 when the similarity of attribute information and the similarity of position computed as the similarity between the past record information and the information about at least a portion of the work environment 4 are both less than a certain value. Upon determining that the past record information does not conform to the information about at least a portion of the work environment 4, the controller 11 does not output the user-selected control program to the robot controller 2.

[0079]   When the past record information does not conform to the information about at least a portion of the work environment 4, the controller 11 searches among the other control programs for a control program for which the past record information conforms to the information about at least a portion of the work environment 4. Upon finding a control program for which the past record information conforms to the information about at least a portion of the work environment 4, the controller 11 may output the found control program to the terminal device 9 as a selection candidate for presentation to the user. In this case, the user selecting the wrong control program is a possibility. The act of the user selecting the wrong control program is also referred to as improper selection of a control program. If the user selects a candidate control program, the controller 11 may estimate improper selection of a control program by the user. The controller 11 may estimate improper selection of a control program by the user on the basis of a result of estimating the suitability of a candidate control program.

[0080]   The terminal device 9 accepts user input selecting a selection candidate of a control program presented to the user. The controller 11 acquires from the terminal

device 9 information specifying the user-selected control program. To increase the accuracy of finding a candidate control program for which the past record information conforms to the information about at least a portion of the work environment 4, the controller 11 may learn user selection results as labeled training data and modify a model to determine whether past record information conforms to information about at least a portion of the work environment 4. The model may be modified so as to improve the accuracy of recognizing objects from a captured image of at least a portion of the work environment 4. A threshold value to be used to make a determination based on similarity may also be adjusted according to user selection results.

[0081] If the controller 11 is unable to find a control program for which the past record information conforms to the information about at least a portion of the work environment 4, the controller 11 assumes that the user has selected the correct control program and estimates a wrongly prepared item among the information about at least a portion of the work environment 4. The presence of a wrongly prepared item in at least a portion of the work environment 4 is also referred to as an improper environment. The controller 11 may estimate an improper environment in at least a portion of the work environment 4. The controller 11 may estimate an improper environment in at least a portion of the work environment 4 on the basis of a result of estimating the suitability of a candidate control program.

[0082] The controller 11 may also detect the cause of an improper environment to be too few or too many objects that should be prepared in at least a portion of the work environment 4, different object placement, or different attribute information about an object. For example, the controller 11 may assume that the user-selected control program is correct and compare past record information mapped to the number of the user-selected control program with an image of the work environment 4 containing objects that the user has placed. The controller 11 may use a result of the comparison as a basis for detecting too few or too many objects that should be prepared in at least a portion of the work environment 4, different object placement, or different attribute information about an object. The controller 11 may estimate an item with a detected difference as a wrongly prepared item.

[0083] The controller 11 may detect an object in an image of the work environment 4 by analyzing the image of the work environment 4. The controller 11 may compute the similarity between an object included in past record information and an object which the user has placed in the work environment 4 and which is detected from an image of the work environment 4. The controller 11 may compute the similarity between attribute information about an object included in past record information and attribute information about an object detected from an image of the work environment 4. The controller 11 may compute the similarity as a numerical value by using

template matching or a trained model generated by machine learning or deep learning. Note that in the case of using a trained model, the trained model can be generated by machine learning using a training dataset containing data such as attribute data about each object in a plurality of past record information.

[0084] The controller 11 may compute a similarity such as the outline or size of objects. The controller 11 may determine that a correct object has been prepared in the work environment 4 when, for example, the similarity of the outline and size of the object is a value representing high similarity, such as being equal to or greater than a predetermined threshold value. The controller 11 may also determine that a correct object has been prepared in the work environment 4 for which the similarity of the outline and size of the object is a certain threshold value or greater.

[0085] When a plurality of objects included in past record information are detected from the work environment 4, the controller 11 may compute the similarity of the outline, size, or the like of the objects between each object included in the past record information and an object detected from an image of the work environment 4. When a plurality of objects are detected from an image of the work environment 4, the controller 11 may compute the similarity of the outline, size, and/or the like of the objects between each object detected from the image of the work environment 4 and an object included in past record information. The controller 11 may compute the similarity of the outline, size, or the like of objects between at least a portion of combinations between each object included in past record information and each object detected from an image of the work environment 4. When a plurality of objects included in past record information include an object that is highly similar to an object detected from an image of the work environment 4, the controller 11 may determine that a correct object is prepared in the work environment 4.

[0086] The controller 11 may estimate a factor that lowers the similarity as the cause of an improper environment. For example, the controller 11 may estimate whether the similarity is lowered due to the wrong position of each object placed in at least a portion of the work environment 4. For example, the controller 11 may estimate whether the similarity is lowered due to the non-preparation of an object that should be prepared in at least a portion of the work environment 4. For example, the controller 11 may estimate whether the similarity is lowered due to the placement of an unneeded object in at least a portion of the work environment 4. As described above, the controller 11 may detect the lack of a necessary object or the presence of an unnecessary object on the basis of a result of a comparison between past record information mapped to the number of a user-selected control program and an image of a user-placed object present in the work environment. The controller 11 may estimate a detected item as the cause of lowered similarity.

[0087] The controller 11 may estimate how at least a portion of the work environment 4 may simply be changed to raise the similarity, and output a required change to the terminal device 9 for presentation to the user. The user may change at least a portion of the work environment 4 on the basis of the presented information, or instruct the robot controller 2 to execute the selected control program without any changes. The controller 11 may learn user instruction details as labeled training data and modify a model to determine whether past record information conforms to information about at least a portion of the work environment 4. A threshold value to be used to make a determination based on similarity may also be adjusted according to user instruction details.

[0088] The controller 11 may estimate a classification of improperness on the basis of the similarity. Specifically, the controller 11 may estimate whether a factor that lowers the similarity is an improper selection or an improper environment. For example, the controller 11 may estimate an improper environment when the similarity is 90% or greater and estimate an improper selection when the similarity is less than 50%.

[0089] The controller 11 may determine whether a placed position is correct for an object determined to be a correct object as an object to be prepared in the work environment 4 among objects detected from an image of the work environment 4. The controller 11 may compute the distance from the position where an object should be placed in the work environment 4 to the position where the object is actually placed, on the basis of the position where the object should be placed in the work environment 4 as specified by data stored in the information processing device 10 and the position of the object in an image of the work environment 4. The controller 11 may compute the distance between the position of a highly similar object included in past record information and the position of an object in an image of the work environment 4. When the computed distance is less than a predetermined threshold value, the controller 11 may determine that the object is placed in the correct position. When the computed distance is less than a certain threshold value, the controller 11 may determine that the object is placed in the correct position. When the computed distance is a predetermined threshold value or greater, the controller 11 may determine that the user has placed an object in the wrong position in the work environment 4.

[0090] The controller 11 may determine whether the user has placed the correct number of objects in the work environment 4. For each object numbering one in data stored in the information processing device 10, the controller 11 may determine whether the object is prepared correctly by comparing the number of highly similar objects determined to be the same as the object specified by the data among objects that the user has placed in the work environment 4. Suppose the case where one object of a first type should be placed in the work environment 4 as specified by data stored in the information processing device 10. In this case, if one object determined to be the same as the object of the first type is present among objects that the user has actually placed in the work environment 4, the controller 11 may determine that the correct number of objects of the first type are placed in the work environment 4. The controller 11 may compute the number of objects that are highly similar to the object of the first type among the objects that the user has actually placed in the work environment 4. If the computed number matches the number of objects of the first type that should be placed in the work environment 4, the controller 11 may determine that the correct number of objects of the first type are placed in the work environment 4. If the computed number is more than the number of objects of the first type that should be placed in the work environment 4, the controller 11 may determine that the correct number of objects of the first type are placed in the work environment 4, or that a sufficient number of objects of the first type are placed in the work environment 4.

[0091] If the objects that the user has placed in the work environment 4 are all lowly similar to the object of the first type, if the similarity of the attribute information about each object is less than a certain threshold value, or if the objects are not similar to the object of the first type, the controller 11 may determine that the user has not placed the object of the first type in the work environment 4, or that the user has placed the wrong object in the work environment 4.

[0092] The controller 11 may compute the number of objects determined to be a correct object as an object to be prepared in the work environment 4, irrespectively of the type of object. If the number of objects determined to be a correct object as an object to be placed in the work environment 4 matches the number of objects that should be prepared in the work environment 4 as specified by data stored in the information processing device 10, the controller 11 may determine that the correct number of objects are prepared. If the number of objects determined to be a correct object as an object to be placed in the work environment 4 is more than the number of objects that should be placed in the work environment 4, the controller 11 may determine that the correct number of objects are placed, or that a sufficient number of objects are placed in the work environment 4.

[0093] Upon determining that the position or number of objects placed in the work environment 4 by the user is wrong, the controller 11 may notify the terminal device 9 that the placement of objects in the work environment 4 is wrong. The controller 11 may notify the terminal device 9 of information indicating the correct position or number of objects that should be placed in the work environment 4, and prompt the user to change the placement to the correct placement.

[0094] Suppose that the user has intentionally placed an object in a different position or placed a different number of objects in the work environment 4. In this case, the terminal device 9 may acquire information indicating

that the user has confirmed that the position and number of objects placed in the work environment 4 by the user are correct, and notify the information processing device 10 that the position and number of objects placed in the work environment 4 by the user are correct. The information processing device 10 may update data so that the position and number of objects placed in the work environment 4 by the user are considered correct.

(Example of procedure of information processing method)

[0095] The robot control system 100 may execute an information processing method including the procedure of the flowchart exemplified in FIGs. 6 and 7. The information processing method may be achieved as an information processing program to be executed by a processor included in the controller 11 of the information processing device 10, the robot controller 2, or the terminal device 9. The information processing program may be stored in a non-transitory computer-readable medium.

[0096] The controller 11 may associate a control program with past record information by executing the procedure of the flowchart in FIG. 6. The controller 11 acquires the selection of a control program from the user (step S1). Specifically, the terminal device 9 accepts user input to select a control program. The controller 11 acquires the selection of a control program from the terminal device 9.

[0097] The controller 11 acquires a captured image of at least a portion of the work environment 4 (step S2). Specifically, the information acquisition device 3 acquires a captured image of at least a portion of the work environment 4, depth information about at least a portion of the work environment 4, or the like as information about at least a portion of the work environment 4. The controller 11 acquires information about at least a portion of the work environment 4 through the information acquisition device 3.

[0098] The controller 11 recognizes objects in at least a portion of the work environment 4 (step S3). The controller 11 acquires attribute information and position information about recognized objects (step S4). The controller 11 stores past record information, including attribute information and position information about objects recognized in at least a portion of the work environment 4, in the memory 12 in association with the control program selected by the user (step S5). After executing the procedure in step S5, the controller 11 ends execution of the procedure of the flowchart in FIG. 6.

[0099] The controller 11 may determine the suitability of a user-selected control program by executing the procedure of the flowchart in FIG. 7.

[0100] The controller 11 acquires the selection of a control program from the user (step S11). Specifically, the terminal device 9 accepts user input to select a control program. The controller 11 acquires the selection of a control program from the terminal device 9.

[0101] The controller 11 acquires a captured image of at least a portion of the work environment 4 (step S12). The controller 11 recognizes objects in at least a portion of the work environment 4 (step S13). The controller 11 acquires attribute information and position information about recognized objects (step S14).

[0102] The controller 11 computes the similarity between past record information associated with control programs and the attribute information and position information about recognized objects (step S15). The controller 11 determines whether the computed similarity is equal to or greater than a threshold value (step S 16). If the computed similarity is equal to or greater than the threshold value (step S16: YES), the controller 11 causes the robot controller 2 to execute the control program selected by the user (step S17). After executing the procedure in step S 17, the controller 11 ends execution of the procedure of the flowchart in FIG. 7.

[0103] If the computed similarity is not equal to or greater than the threshold value (step S16: NO), that is, if the computed similarity is less than the threshold value, the controller 11 determines whether a control program similar to the task that the user wants to be performed exists (step S18). Specifically, the controller 11 determines whether a control program that is associated with past record information similar to information about at least a portion of the work environment 4 prepared by the user exists among control programs stored in the memory 12. The controller 11 may determine whether a control program associated with past record information that is highly similar to information about at least a portion of the work environment 4 prepared by the user exists.

[0104] If a similar control program exists (step S18: YES), the controller 11 extracts the similar control program (step S19). The controller 11 outputs information specifying the extracted control program to the terminal device 9 for presentation to the user. The controller 11 acquires the selection of a control program from the user (step S20). Specifically, the terminal device 9 accepts user input to select a control program. The controller 11 acquires the selection of a control program from the terminal device 9. After executing the procedure in step S20, the controller 11 proceeds to the procedure in step S17 and causes the robot controller 2 to execute the control program selected by the user.

[0105] If a similar control program does not exist (step S18: NO), the controller 11 estimates a factor that lowers the similarity to existing past record information in at least a portion of the work environment 4, and outputs the estimated factor to the terminal device 9 for display (step S21). After executing the procedure in step S21, the controller 11 ends execution of the procedure of the flowchart in FIG. 7. After executing the procedure in step S21, the controller 11 may confirm that the user has changed at least a portion of the work environment 4 and return to the determination procedure in step S18.

(Summary)

[0106] As described above, according to the robot control system 100, information processing device 10, and information processing method as in this embodiment, the suitability of a candidate control program to control the robot 1 may be estimated from a plurality of control programs. A determination may be made as to whether a user-selected program conforms to at least a portion of the work environment 4. This reduces the likelihood of the user selecting the wrong control program. This may also avoid situations in which the robot 1 begins a task while at least a portion of the work environment 4 is prepared improperly or the wrong control program is selected. The result may be a reduced burden on the user.

[0107] According to this embodiment, a determination may be made as to whether at least a portion of the work environment 4 and the selection of a control program are suitable by comparing attribute information and position information about objects present in at least a portion of the work environment 4 with past record information associated with the control program. Simply checking that the workpieces 8 or the like are organized in the work environment 4 may not ensure the successful completion of a task by the robot 1 according to the selected control program. Conversely, even if the workpieces 8 or the like are not organized in the work environment 4, the robot 1 may still complete a task successfully according to the selected control program. Making a comparison between information about at least a portion of the work environment 4 and past record information or making a determination based on similarity may allow for a flexible response in tasks by the robot 1. As a result, the robot 1 may execute tasks efficiently.

[0108] The suitability of a control program may be determined with respect to every task that the robot 1 is to perform, or with respect to a combined series of multiple tasks that the robot 1 is to perform.

[0109] The efficiency when using the robot 1 may be improved. The efficiency of cooperative tasks involving the robot 1 may be improved. Cooperative tasks include tasks performed by a human and the robot 1 working together, tasks performed by robots 1 working together, or tasks performed by the robot 1 and another machine working together. Cooperative tasks include collaborative tasks performed by a human and the robot 1 working together.

(Other embodiments)

[0110] In this embodiment, the robot control system 100 may be deployed at industrial sites for industrial products, food processing sites where foodstuffs are handled, or sites where cosmetics or pharmaceuticals are produced.

[0111] In this embodiment, the robot control system 100 may be used to control a communication robot, service robot, or other robot 1 that interacts with users. For example, when the robot 1 has a camera or other information acquisition device 3, the robot control system 100 may determine the suitability of the selection of a control program on the basis of a result of recognizing the face of a user with whom to interact or provide a service. The robot control system 100 may be applied to cases such as when the control program needs to be changed in response to a change of circumstances, such as when the user is wearing glasses or a mask, for example.

[0112] The controller 11 of the information processing device 10 may acquire usage information indicating usage conditions of a candidate control program selected by the user, and estimate the suitability of the candidate on the basis of the similarity and the usage information. The usage information may represent work hours in a day, or work time in a year or a month. The usage information may also represent a user who causes the robot 1 to perform a task. The usage information may also represent a place where the robot 1 is caused to perform a task. The usage information may also represent the most recent time when the robot 1 was caused to perform a task or the most recent frequency at which the robot 1 was caused to perform a task.

[0113] When a control program to be executed by the robot controller 2 is determined, the controller 11 may newly associate prepared environmental information corresponding to at least a portion of the work environment 4 of the robot 1 with the determined control program as past record information. New past record information to be associated with a determined control program is also referred to as third environmental information. The association of third environmental information with a control program is also referred to as the recording of third environmental information. The recording of third environmental information may be carried out whether a user-selected candidate is determined to be suitable or estimated to be unsuitable. The recording of third environmental information may also be carried out upon receiving an instruction to use a user-selected candidate as-is, despite the controller 11 having determined that the user-selected candidate is unsuitable. When the controller 11 has determined that the user-selected candidate is unsuitable, the recording of third environmental information may be carried out if the user gives an instruction to use another candidate. Associating third environmental information with a control program, that is, carrying out the recording of third environmental information, may increase the accuracy with which the controller 11 estimates the suitability of a candidate control program. Specifically, for example, artificial intelligence (AI) may be used to update via retraining the environmental information to which a control program is to be applied, or to update via retraining a model with which the controller 11 estimates the suitability of a candidate control program.

[0114] The controller 11 may use the third environmental information as a basis to correct a determination criterion for the suitability of a candidate control program.

For example, in the case where a candidate is estimated to be suitable when the similarity is 90% or greater, the controller 11 may use the third environmental information as a basis to correct the determination criterion so that a candidate is also estimated to be suitable when the similarity is 80% or greater. In the case where an improper environment is estimated when the similarity is at least 80% and less than 90%, the controller 11 may correct the determination criterion so that an improper environment is estimated when the similarity is at least 75% and less than 90%, and an improper selection is estimated when the similarity is less than 75%.

[0115] An allowable range for determining a similarity of 90% may change. For example, the relationship between information about at least a portion of the work environment 4 and past record information that had a similarity of less than 90% before correction of the determination criterion may have a similarity of 90% or more after correction of the determination criterion.

[0116] The controller 11 may detect an improper environment or an improper selection on the basis of the positional relationship of a plurality of objects. The controller 11 may detect an improper environment or an improper selection on the additional basis of information associating past record information with a control program.

[0117] In this embodiment, the robot control system 100 determines the suitability of a control program selected by the user. When the user is to select a control program, the robot control system 100 may cause the terminal device 9 to display a candidate control program. In this case, the controller 11 of the robot control system 100 may acquire information via the robot controller 2, the terminal device 9, the information acquisition device 3, or the like, such as attribute information about the robot 1 that the user is expected to use, information about the user who is expected to use the robot 1, or information about a recognized work object or the like expected to be involved in a task. The controller 11 may extract, as a candidate control program, a control program that is executed frequently in a certain period or a control program that a specific user executes frequently with respect to the robot 1 that the user is expected to use, a robot of the same type as the robot 1 expected to be used, or a work object expected to be involved in a task, for example. In this case, the robot control system 100 may also compute an indicator referred to as the degree of association. The controller 11 of the information processing device 10 may, for example, compute the degree of association so that a high priority ranking is given to a control program that has been executed frequently in a certain period going back from the present. The controller 11 may compute the degree of association so that a high priority ranking is given to the most recently executed control program. The controller 11 may compute the degree of association so that a high priority ranking is given to the control program most recently executed by, or a control program executed by, the user who is preparing the work environment 4 to cause the robot 1 to perform

a task. The controller 11 may extract a control program on the basis of the value of the computed indicator such as the degree of association.

[0118] The foregoing describes embodiments of the robot control system 100, but in the present disclosure, an embodiment may also be achieved as a method or program for implementing a system or device, or as a storage medium (such as an optical disc, magnetooptical disc, CD-ROM, CD-R, CD-RW, magnetic tape, hard disk, or memory card, for example) in which a program is recorded. The program may be stored in a non-transitory computer-readable medium.

[0119] An embodiment in the form of a program is not limited to an application program such as object code compiled by a compiler or program code to be executed by an interpreter, and may also be in a form such as a program module incorporated into an operating system. The program may or may not be configured so that all processing is performed solely in a CPU on a control board. The program may also be configured to be implemented, in part or in full, by another processing unit mounted on an expansion board or expansion unit added to the board as needed.

[0120] The foregoing description of embodiments according to the present disclosure is based on the drawings and examples, but note that a person skilled in the art could make various variations or revisions on the basis of the present disclosure. Consequently, it should be understood that these variations or revisions are included in the scope of the present disclosure. For example, the functions and the like included in each component and the like may be rearranged in logically non-contradictory ways. A plurality of components or the like can be combined into one, or a single component can be divided.

[0121] In the present disclosure, all constituent features described herein and/or all methods or all steps of processes disclosed herein can be combined in any combinations, except for combinations in which these features would be mutually exclusive. Each of the features described in the present disclosure can be replaced by alternative features that work for the same, equivalent, or similar purposes, unless explicitly denied. Therefore, unless explicitly denied, each of the disclosed features is merely one example of a comprehensive series of same or equal features.

[0122] An embodiment according to the present disclosure is not limited to any of the specific configurations of the embodiments described above. In the present disclosure, embodiments can be extended to all novel features described herein or combinations thereof, or to all novel methods or processing steps described herein or combinations thereof.

[0123] In the present disclosure, qualifiers such as "first" and "second" are identifiers for distinguishing configurations. The numerals denoting the configurations distinguished by qualifiers such as "first" and "second" in the present disclosure are interchangeable. For example, the identifiers "first" and "second" may be inter-

changed between the first tray 6 and the second tray 7. The identifiers are interchanged at the same time. The configurations are still distinguished after the interchange of the identifiers. The identifiers may be removed. The configurations with the identifiers removed therefrom are distinguished by signs. The description of identifiers such as "first" and "second" in the present disclosure shall not be used as a basis for interpreting the order of the configurations or the existence of identifiers with smaller numbers.

REFERENCE SIGNS

[0124]

100 robot control system (1: robot, 2: robot controller, 3: information acquisition device, 4: work environment, 5: workbench, 6: first tray, 7: second tray, 8: workpiece)
9 terminal device
10 information processing device (11: controller, 12: memory)
80 network

Claims

1. An information processing device comprising:

   a controller that estimates the suitability of a candidate first control program to control a first robot from a plurality of control programs to control a robot which are recorded in a memory, wherein the controller is configured to
   acquire first environmental information indicating a work environment of the first robot,
   acquire second environmental information indicating an environment in which the first control program is to be executed, and
   estimating the suitability of a candidate first control program on the basis of a similarity between the first environmental information and the second environmental information.

2. The information processing device according to claim 1, wherein
   the controller estimates the suitability of the candidate when the user has selected the candidate.

3. The information processing device according to claim 1 or 2, wherein
   the controller estimates an improper selection of a control program by the user on the basis of a result of the estimation regarding the candidate.

4. The information processing device according to any one of claims 1 to 3, wherein
   the controller estimates an improper environment of the work environment on the basis of a result of the estimation regarding the candidate.

5. The information processing device according to claim 4, wherein
   the controller detects, as the improper environment, too few or too many of an object that should be prepared in the vicinity of the first robot, different placement of the object, or different attribute information about the object.

6. The information processing device according to any one of claims 1 to 5, wherein
   the controller estimates a classification of improperness on the basis of the similarity.

7. The information processing device according to any one of claims 1 to 6, wherein

   the controller is configured to
   acquire usage information indicating usage conditions of the candidate, and estimate the suitability of the candidate on the basis of the similarity and the usage information.

8. The information processing device according to any one of claims 1 to 7, wherein
   when a first control program to be executed by the first robot is determined, the controller causes the memory to record third environmental information indicating an environment in which control of the first robot is to be performed, in association with the first control program.

9. The information processing device according to claim 8, wherein
   the controller corrects a determination criterion for the suitability of the candidate on the basis of the third environmental information.

10. The information processing device according to any one of claims 1 to 9, wherein
    the controller detects an improper environment or an improper selection on the basis of information pertaining to the position of an object present in the work environment.

11. The information processing device according to any one of claims 1 to 10, wherein
    the object present in the work environment includes peripheral equipment placed in the work environment.

12. The information processing device according to claim 8, wherein
    the controller computes a similarity for information pertaining to attribute information about an object present in the work environment.

13. A robot controller that controls the robot by executing a control program outputted upon being determined to be in a suitable state in the information processing device according to any one of claims 1 to 12.

14. A robot control system comprising: the information processing device according to any one of claims 1 to 12; the robot controller according to claim 13; and the robot.

15. An information processing method comprising:

acquiring, by an information processing device that estimates the suitability of a candidate first control program to control a first robot from a plurality of control programs to control a robot which are recorded in the information processing device, first environmental information indicating a work environment of the first robot;
acquiring, by the information processing device, second environmental information indicating an environment in which the first control program is to be executed; and
estimating, by the information processing device, the suitability of a candidate first control program on the basis of a similarity between the first environmental information and the second environmental information.
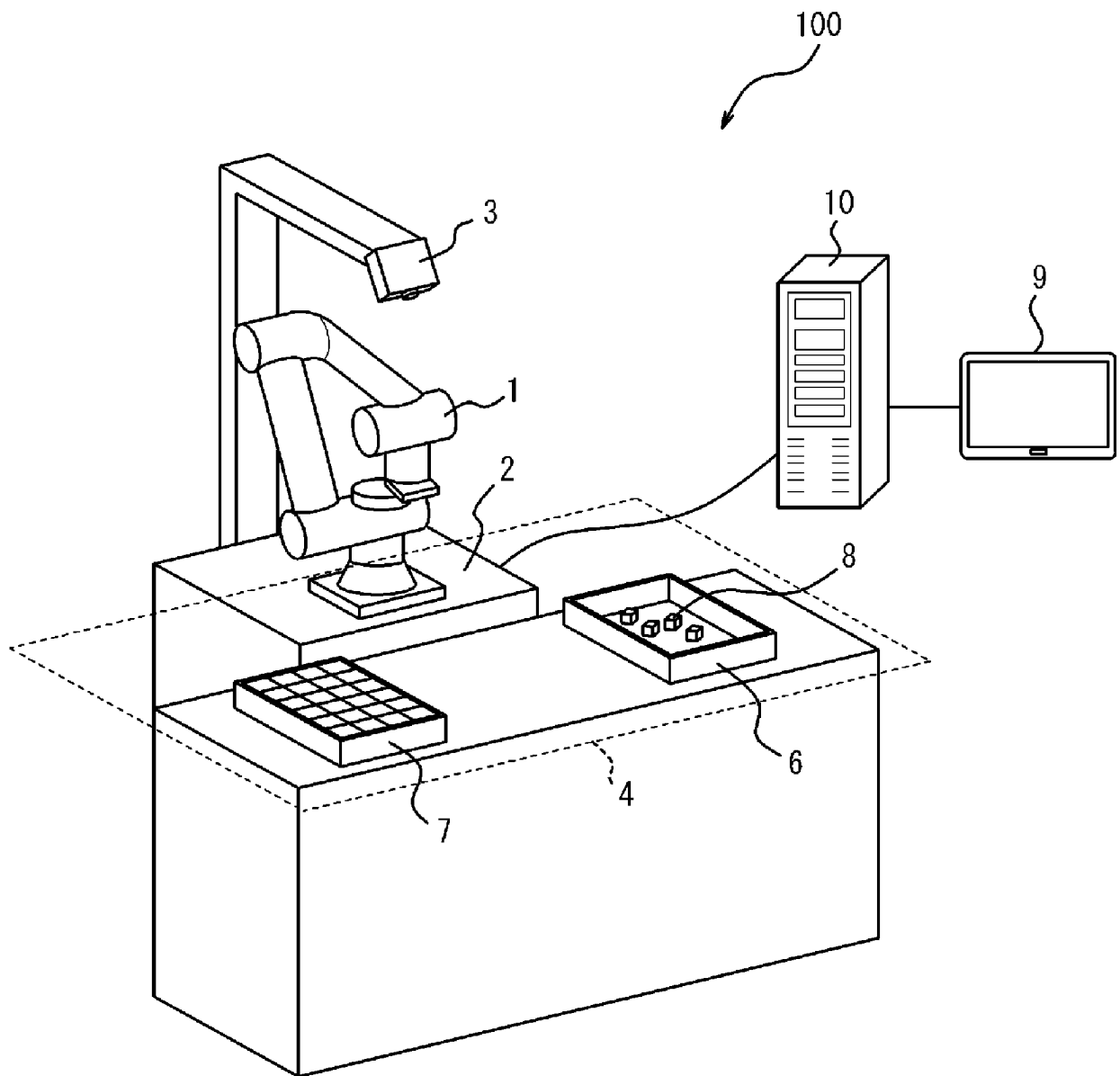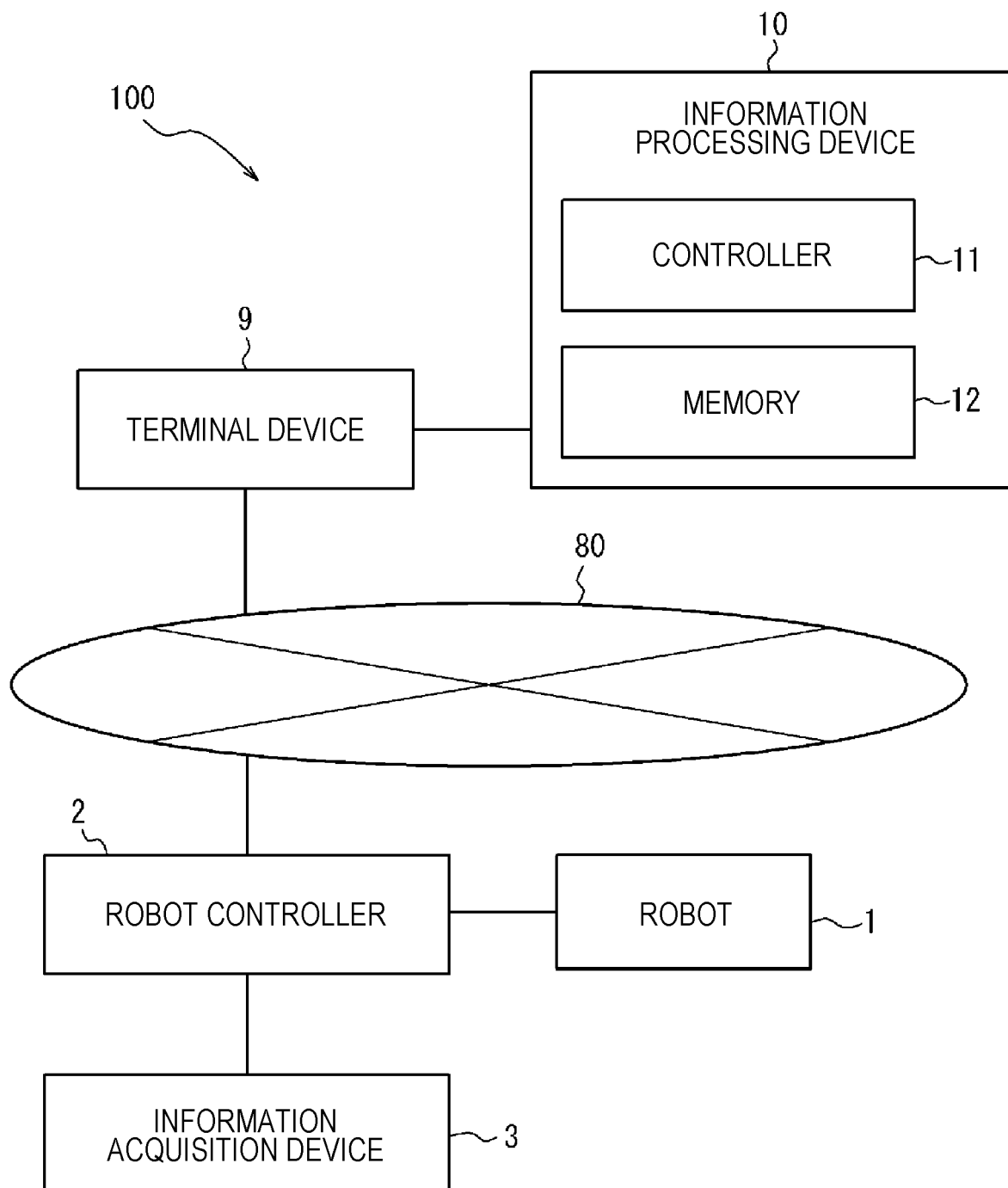
FIG. 1

FIG. 2

FIG. 3

FIG. 4
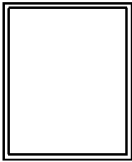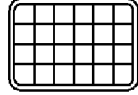
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NUMBER	1	1	1	8	...
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OUTLINE					...
TEXTURE					...
SIZE	W1 × D1 × H1	W2 × D2 × H2	W3 × D3 × H3	W4 × D4 × H4	...
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FIG. 5
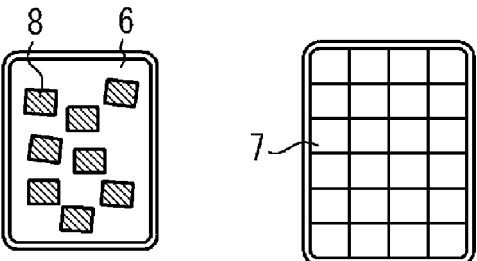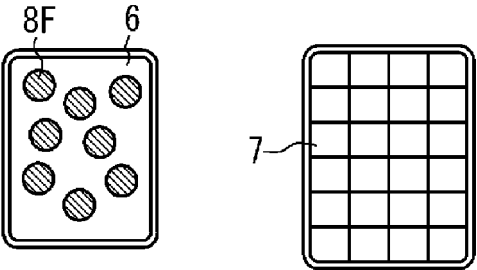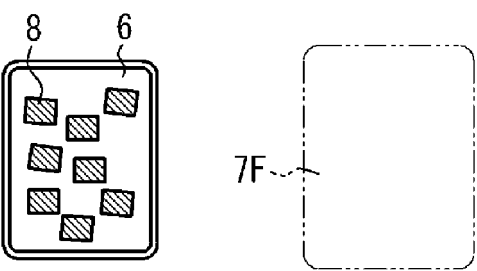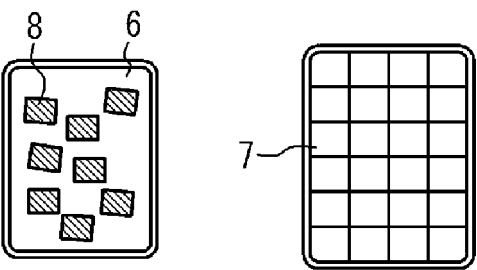
TYPE	PROGRAM	IMAGE OF WORK ENVIRONMENT
CORRECT COMBINATION	STORED DATA No. 28	
WRONG WORKPIECES	SELECTED DATA No. 28	
TRAY NOT SET	SELECTED DATA No. 28	
WRONG PROGRAM SELECTED	SELECTED DATA No. 14	

FIG. 6

```
                    ┌─────────────┐
                    │    START    │
                    └─────────────┘
                           │
                           ▼
   ┌────────────────────────────────────────────┐
   │  ACQUIRE USER SELECTION OF PROGRAM          │  ⌇ S1
   └────────────────────────────────────────────┘
                           │
                           ▼
   ┌────────────────────────────────────────────┐
   │  ACQUIRE INFORMATION ABOUT AT LEAST         │  ⌇ S2
   │  PORTION OF WORK ENVIRONMENT                │
   └────────────────────────────────────────────┘
                           │
                           ▼
   ┌────────────────────────────────────────────┐
   │  RECOGNIZE OBJECTS IN AT LEAST              │  ⌇ S3
   │  PORTION OF WORK ENVIRONMENT                │
   └────────────────────────────────────────────┘
                           │
                           ▼
   ┌────────────────────────────────────────────┐
   │  ACQUIRE ATTRIBUTE INFORMATION AND POSITION │  ⌇ S4
   │  INFORMATION ABOUT RECOGNIZED OBJECTS       │
   └────────────────────────────────────────────┘
                           │
                           ▼
   ┌────────────────────────────────────────────┐
   │  STORE PAST RECORD INFORMATION IN           │  ⌇ S5
   │  ASSOCIATION WITH SELECTED PROGRAM          │
   └────────────────────────────────────────────┘
                           │
                           ▼
                    ┌─────────────┐
                    │     END     │
                    └─────────────┘
```

FIG. 7

START

ACQUIRE USER SELECTION OF PROGRAM —S11

ACQUIRE INFORMATION ABOUT AT LEAST PORTION OF WORK ENVIRONMENT —S12

RECOGNIZE OBJECTS IN AT LEAST PORTION OF WORK ENVIRONMENT —S13

ACQUIRE ATTRIBUTE INFORMATION AND POSITION INFORMATION ABOUT RECOGNIZED OBJECTS —S14

COMPUTE SIMILARITY —S15

S16

SIMILARITY ≥ THRESHOLD VALUE? — NO

YES

S18

PROGRAM SIMILAR TO TASK EXISTS? — NO

YES

S21

DISPLAY FACTOR THAT LOWERS SIMILARITY

EXTRACT PROGRAM SIMILAR TO WORK ENVIRONMENT —S19

ACQUIRE USER SELECTION OF PROGRAM —S20

EXECUTE SELECTED PROGRAM —S17

END

INTERNATIONAL SEARCH REPORT

	International application No.
	PCT/JP2022/036312

A. CLASSIFICATION OF SUBJECT MATTER

B25J 9/22(2006.01)i
FI: B25J9/22 Z

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

B25J9/22

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Published examined utility model applications of Japan 1922-1996
Published unexamined utility model applications of Japan 1971-2022
Registered utility model specifications of Japan 1996-2022
Published registered utility model applications of Japan 1994-2022

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	JP 2020-099976 A (SEIKO EPSON CORP.) 02 July 2020 (2020-07-02) paragraphs [0011]-[0027], [0081], fig. 1-7	1-7, 10-11, 13-15
Y		8-9, 12
Y	JP 2018-051652 A (HITACHI, LTD.) 05 April 2018 (2018-04-05) paragraphs [0013]-[0036], fig. 1	8-9, 12
Y	JP 2005-138245 A (YASKAWA ELECTRIC CORP.) 02 June 2005 (2005-06-02) paragraphs [0012]-[0020], fig. 1-11	8-9, 12
A	JP 2006-343828 A (FANUC LTD.) 21 December 2006 (2006-12-21) entire text, all drawings	1-15
A	JP 2020-016446 A (CANON INC.) 30 January 2020 (2020-01-30) entire text, all drawings	1-15
A	JP 2020-135045 A (FANUC LTD.) 31 August 2020 (2020-08-31) entire text, all drawings	1-15

☑ Further documents are listed in the continuation of Box C.   ☑ See patent family annex.

*	Special categories of cited documents:	"T"	later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"A"	document defining the general state of the art which is not considered to be of particular relevance		
"E"	earlier application or patent but published on or after the international filing date	"X"	document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"L"	document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	"Y"	document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"O"	document referring to an oral disclosure, use, exhibition or other means		
"P"	document published prior to the international filing date but later than the priority date claimed	"&"	document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
29 November 2022	**13 December 2022**

Name and mailing address of the ISA/JP	Authorized officer
Japan Patent Office (ISA/JP) **3-4-3 Kasumigaseki, Chiyoda-ku, Tokyo 100-8915** **Japan**	
	Telephone No.

Form PCT/ISA/210 (second sheet) (January 2015)

INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2022/036312

C.   DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 2021/0122051 A1 (SAMSUNG SDS CO., LTD.) 29 April 2021 (2021-04-29) entire text, all drawings	1-15

Form PCT/ISA/210 (second sheet) (January 2015)

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/JP2022/036312

Patent document cited in search report			Publication date (day/month/year)	Patent family member(s)			Publication date (day/month/year)
JP	2020-099976	A	02 July 2020	(Family: none)			
JP	2018-051652	A	05 April 2018	(Family: none)			
JP	2005-138245	A	02 June 2005	(Family: none)			
JP	2006-343828	A	21 December 2006	US	2006/0276934	A1	
				entire text, all drawings			
				EP	1731273	A2	
				CN	1876334	A	
JP	2020-016446	A	30 January 2020	(Family: none)			
JP	2020-135045	A	31 August 2020	US	2020/0254577	A1	
				entire text, all drawings			
				DE	102020200638	A1	
				CN	111558842	A	
US	2021/0122051	A1	29 April 2021	KR	10-2021-0048865	A	

Form PCT/ISA/210 (patent family annex) (January 2015)

REFERENCES CITED IN THE DESCRIPTION

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- JP 2021158480 A **[0001]**

- JP 2021030407 A **[0004]**